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APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL ALTERNATE MISSION PLANS

VOLUME III

LUNAR ALTERNATE RENDEZVOUS

Orbital Mission Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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PROJECT APOLLO

APOLLO 10 (MISSION F) SPACECRAFT OPERATIONAL ALTERNATE MISSION PLANS VOLUME III - LUNAR ALTERNATE RENDEZVOUS

By Ronny H. Moore
Orbital Mission Analysis Branch

April 9, 1969

MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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HOUSTON, TEXAS

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ALTERNATE MISSION PLANS

VOLUME III - LUNAR ALTERNATE RENDEZVOUS

By Ronny H. Moore

1.0 SUMMARY

This document, which is Volume III of the operational alternate mission plan for Apollo 10 (Mission F), presents the operational lunar orbital alternate rendezvous plans. Four LM-active alternate rendezvous plans and procedures which fulfill mission test objectives are presented. With the exception of the LM-active modified football alternate, the alternate plans are based on various postulated nonnominal situations in which the basic coelliptic rendezvous sequence is used.

Although the operational plans were generated for the May 17 mission launch date, they are generally applicable to any launch date and time. Based on formulated ground rules and known constraints, the operational plans are feasible from a trajectory standpoint; that is, the plans do not impose unique maneuvers or procedures, additional crew training, or new software requirements for the onboard or the ground support capabilities. The plans update those published in the preliminary alternate mission plan (ref. 1).

2.0 INTRODUCTION

The total mission planning effort for Apollo 10 (Mission F) includes alternate mission plans for both the earth orbital and the lunar orbital mission phases. The preflight planning effort is significant because certain mission test objectives can be accomplished if proper preparations are made for development of the operational alternate mission plans, techniques, procedures, and mission rules. Therefore, the purpose of this document is to present four operational alternate plans which are feasible based on certain ground rules and known constraints.

The ground rules and rendezvous techniques and the operational lunar orbital alternate rendezvous plans are presented for the following nonnominal situations.

1. Inability (or nondesire) to jettison the descent stage

2. Loss of useful APS only

3. Loss of useful DPS only

4. Loss of both APS and DPS

Maneuver summaries, relative motion plots, daylight/darkness histories, and MSFN tracking summaries are presented for all the alternate rendezvous plans.

3.0 SYMBOLS AND DEFINITIONS

AGS	abort guidance system
APS	ascent propulsion system
CDH	constant differential height
CES	control electronics system
CSI	coelliptic sequence initiation
CSM	command and service modules
Δh	differential altitude between active and inactive vehicle orbits
ΔV	total change in velocity caused by thrusting
DOI	descent orbit insertion
DPS	descent propulsion system
F.T.	full throttle
G.m.t.	Greenwich mean time
g.e.t.	ground elapsed time from earth lift-off
h_a	apocynthion altitude referenced to the landing site
h_p	pericynthion altitude referenced to the landing site

IMU	inertial measurement unit
LM	lunar module
LPO	lunar parking orbit
MSFN	Manned Space Flight Network
PDI	powered descent initiation
PGNCS	primary guidance and navigation control subsystem
RCS	reaction control system
RTCC	Real-Time Computer Complex
SM	service module
SPS	service propulsion system
TEI	transearth injection
TM	telemetry
TPI	terminal phase initiation
TPF	terminal phase finalization
VHF	very high frequency
alternate rendezvous	any deviation from the nominal rendezvous to accomplish mission objectives
APS rendezvous	any rendezvous during which the APS is the primary propulsion system and no DPS is available
coelliptic sequence	a rendezvous technique to establish, prior to TPI and at a different altitude, an active-vehicle (chaser) orbit and to establish a desired relative condition at a selected time for TPI
DPS rendezvous	any rendezvous during which the DPS is the primary propulsion system and no APS is required

football rendezvous — a relative condition between the CSM and LM initiated by a radial separation which places the vehicles in equiperiod orbits such that rendezvous occurs one orbit later

4.0 INPUT DATA, GUIDELINES, AND ASSUMPTIONS

The following guidelines and assumptions were used to design the alternate rendezvous plans.

1. LM test objectives will have first priority.

2. Alternate rendezvous time lines will not exceed the nominal rendezvous time line.

3. No additional crew training will be required for alternates.

4. No additional RTCC or onboard processors will be necessary.

5. Alternate plans will be consistent with current spacecraft, crew, and operational constraints.

6. The CSM will be nominal in all alternates.

7. The sequence of events will contain no more maneuvers than the nominal rendezvous.

8. The CSI-CDH coelliptic sequence will be used whenever possible.

9. RCS backup capability will be maintained on any APS-only rendezvous.

Sources of input data used to design the alternate rendezvous are summarized as follows. LM test objectives are discussed in detail in the mission requirements document (ref. 2), while the LM operational constraints were obtained from the Apollo Operations Handbook (ref. 3). The spacecraft operational trajectory (ref. 4) presented the operational rendezvous time line and the initial vectors used to generate the alternate plans. Weights and engine performance parameters were obtained from the Spacecraft Operational Data Books (refs. 5, 6, and 7) and from reference 8. The MSFN tracking was generated based on requirements defined by Flight Control Division (ref. 9) and by use of MSFN stations defined by Goddard in reference 10.

5.0 BASIC RENDEZVOUS TECHNIQUES

Except for the modified football rendezvous, the basic rendezvous technique that is used for the alternate rendezvous plans is the CSI-CDH coelliptic sequence. The objective of the pre-CSI logic is to apply a maneuver (CSI) which will result in the desired TPI conditions being obtained by the active vehicle at a selected TPI time after a coelliptic maneuver (CDH) has been performed at a selected time after CSI. This technique is used in the Apollo 10 (Mission F) rendezvous. A maneuver summary of the Apollo 10 (Mission F) rendezvous is presented in table I. Although the CSI-CDH technique is used, two preceding maneuvers (phasing and insertion) are required to establish the proper conditions so that the coelliptic sequence of the Apollo 10 (Mission F) rendezvous will be nearly identical to the planned lunar landing mission sequence. A similar scheme is used in the alternate plans when advisable; however, a CSI-CDH rendezvous sequence may be arranged with only one maneuver (phasing) so that rendezvous can occur one revolution earlier. This single pre-CSI maneuver technique is used in the APS-only alternate rendezvous to conserve APS power and time. The DOI is a maneuver designed to enable the LM to brake out of the LPO and to descend over a specific landing site. Although it is not designed specifically as a rendezvous maneuver, it may be altered to arrange for more favorable conditions for some alternates. The phasing maneuver and, where desirable, insertion are planned so that certain conditions are obtained during the rendezvous sequence. The conditions are as follows.

1. The TPI maneuver will occur at the midpoint of darkness on a LM-to-CSM elevation angle of 26.6°.

2. Coelliptic Δh will be 15 n. mi. with the LM below the CSM.

3. The CSI maneuver will occur at the first apocynthion after insertion or after phasing on the shortened rendezvous sequence.

4. The CDH will occur one-half period after CSI.

All of these conditions exist during the nominal Apollo 10 (Mission F) rendezvous.

The other rendezvous technique considered is the modified football, which is initiated by a radial separation maneuver. Rendezvous could be accomplished exactly one revolution after the radial separation maneuver if an identical radial maneuver is performed in the opposite direction along with terminal line-of-sight braking. However, the ΔV requirement for braking is reduced if a standard TPI is performed at the chaser pericynthion to increase the travel angle during terminal phase from 90° to 130°. The football technique is suggested as an alternate exercise if neither main LM propulsion system is usable or if a complete rendezvous is not allowed for some other reason.

6.0 ALTERNATE RENDEZVOUS PLANS AND PROCEDURES FOR VARIOUS SITUATIONS

The alternate rendezvous plans are designed for situations during the Apollo 10 (Mission F) lunar orbit when the nominal rendezvous cannot be attempted.

6.1 Alternate 1a, DPS Unstaged

A DPS rendezvous alternate 1a may be flown if it is apparent that the descent stage cannot be staged, either because of a failure of the staging mechanism or because of a desire to retain the DPS for later docked maneuvers (i.e., a docked DPS TEI). The sequence of events for this alternate rendezvous is presented in table II.

The alternate 1a sequence is exactly the same as the nominal rendezvous sequence presented in table I except that descent staging, which occurs nominally 10 minutes prior to insertion, is not performed. All maneuvers prior to insertion are performed as in the operational sequence. Insertion, CSI, and TPI are performed with DPS. The CDH is performed with the LM RCS because it will normally be a small maneuver. However, if the required LM RCS burn time is greater than or equal to 10.0 seconds ($\Delta V \approx 4$ fps), the maneuver will be performed with the DPS at 10 percent thrust to avoid approaching the four-jet +X RCS impingement limit of 15-seconds for burn duration.

Because the unstaged LM is somewhat difficult and inefficient to maneuver during the braking phase, the CSM will perform the braking maneuvers and docking. Thus, after this rendezvous, the orbit will be approximately 43 n. mi. by 62 n. mi. If it is not desirable to perform TEI in this orbit, a docked circularization maneuver would be performed at apogee approximately one revolution later. The posigrade SPS burn of 26.1 fps will be approximately 2.2 seconds in duration in the docked configuration. The LM might not be jettisoned prior to circularization because it may be desirable to perform TEI with the DPS. All the rendezvous alternate 1a parameters and relative motion will be the same as for the nominal rendezvous. The only differences in profiles are the burn times of insertion and subsequent maneuvers caused by use of different propulsion systems and a heavier vehicle. A maneuver summary for alternate 1a is presented in table II, and the relative motion is presented in figure 1. The MSFN coverage and the daylight/darkness history are shown in figure 7. Note that TPI, nominally performed with the RCS, will be executed with the DPS at 10 percent full thrust to avoid a lengthy RCS burn. As a result, radar lock-on must be broken to perform TPI. However, the current nominal plan is to execute TPI with the +X RCS; with open interconnect, which also requires momentary loss of radar lock-on.

6.2 Alternate 1b, APS Inoperative

The DPS rendezvous alternate 1b, may be flown if the APS engine cannot be used or if ascent battery power is limited. The latter situation would make it desirable to remain on descent power as long as possible. The sequence of events is identical to a DPS rendezvous alternate 1a except that descent staging can occur when the descent stage is no longer needed. Staging is planned to occur after CDH so that TPI and braking (TPF) can be performed with the LM RCS and, therefore, a nominal terminal phase can be accomplished.

The recommended staging sequence is as follows.

1. Perform a 2-fps retrograde maneuver with LM RCS -X jets at a convenient time after the CDH maneuver.

2. Stage.

3. Perform a 2-fps posigrade maneuver with the +X thrusters.

The staging sequence will place the descent stage below both the LM and the CSM and will prevent any recontact problem. The 2-fps retrograde maneuver places the LM on a slightly different ellipse, and by staging and performing a 2-fps posigrade maneuver with the ascent stage, the ascent stage will return to the original ellipse. The relative motion of the descent stage with respect to the ascent stage is shown in figure 4. The staging sequence is performed at a convenient time after the CDH maneuver such that tracking and pre-TPI procedures between CDH and TPI are not disturbed. The DPS stage is retained until after the CDH maneuver to conserve APS power. The maneuver summary for alternate 1b is presented in table III, and the relative motion, which is the same as that for DPS rendezvous alternate 1a, is shown in figure 1. The MSFN coverage summary and the daylight/darkness history are presented in figure 8.

6.3 Alternate 2, APS Rendezvous

An APS rendezvous may be flown when the DPS cannot be used. The sequence of events for this rendezvous is presented in table IV.

To provide adequate separation distance at DOI, the CSM performs the minifootball maneuver as in the nominal sequence. The staging sequence recommended during the minifootball is the following.

1. Approximately 15 minutes prior to DOI, perform a 2-fps posigrade maneuver with the LM RCS (-X jets).

2. Stage the DPS.

3. Perform a 2-fps retrograde maneuver (+X jets).

The sequence of maneuvers will place the descent stage behind and above both the CSM and LM and will prevent any recontact problems. The relative motion of the descent stage with respect to the CSM is shown in figure 5. By comparison of this figure with figure 2, it is apparent that no recontact problems should occur. To conserve APS power, the DPS stage is retained until just prior to DOI. Because DOI, which is performed with the APS, is targeted to achieve a 40-n. mi. pericynthion altitude, any slight perturbations in the LM trajectory caused by the staging sequence will not be significant.

Approximately 195° prior to the landing site, the APS performs DOI to approximately a 40-n. mi. pericynthion altitude. The choice of pericynthion altitude is based on the LM RCS impingement limit for the ascent stage (a continuous burn of approximately 55 sec). If the APS is lost, any backup RCS burns must be less than this limit. With a 40-n. mi. pericynthion altitude, the largest possible RCS burn (CDH) is approximately 50.4 seconds in duration. At pericynthion after DOI, the APS performs a phasing maneuver targeted to set up relative conditions so that the coelliptic rendezvous sequence to place TPI at the midpoint of darkness will result in a ΔH of 15 n. mi. when CSI and CDH are performed on the next apsis crossings. Phasing raises LM apocynthion altitude to approximately 102 n. mi., at which point CSI is performed. The CDH maneuver is performed one-half period later at pericynthion. The CSI maneuver raises pericynthion altitude to approximately 46 n. mi. so that the retrograde APS CDH can place the LM in a coelliptic orbit 15 n. mi. below the CSM. The CSI and CDH maneuvers could be performed by use of the RCS thrusters with the APS interconnect because sufficient APS propellant will still be available. The TPI maneuver occurs approximately 35 minutes after CDH on a LM-to-CSM elevation angle of 26.6°. Terminal phase occurs as in the nominal rendezvous profile, although one revolution sooner. Alternate 2 contains one less maneuver (insertion) than the operational sequence to permit rendezvous one revolution earlier, which conserves the APS power supply. A similar sequence is planned as part of the nominal PDI abort procedure for both the F and G missions; therefore, no new crew training or unique procedures are introduced here. For alternate 2, the maneuver summary is shown in table IV, the relative motion in figure 2, the MSFN coverage and the daylight/darkness history in figure 9.

6.4 Alternate 3, Modified Football

In all rendezvous plans, the sequence is begun with a separation maneuver. The maneuver is a small radial maneuver that places the CSM and LM in equiperiod orbits to enable the vehicles to arrive at the same position one orbit later. The relative motion caused by the maneuver is termed minifootball. A 2.5-fps radially-down maneuver performed by the CSM will place the CSM approximately 1.9 n. mi. ahead of the LM at DOI. The DOI maneuver normally is performed 180° after the separation maneuver or halfway through the minifootball. Likewise, a 2.5-fps radially-up maneuver will place the CSM approximately 1.9 n. mi. behind the LM at DOI. If no other type of rendezvous is possible because of unusable DPS and APS engines or for some other reason, a modified football could be performed to check out the rendezvous radar and the VHF ranging. If the radial separation is 80 fps instead of 2.5 fps, the maximum range obtained is approximately 61 n. mi. Close approach would occur one orbit later if no maneuvers were performed. A near nominal terminal phase can be accomplished by performing TPI on an elevation angle of 26.6° and at the midpoint of darkness but with a Δh at TPI of approximately 14.6 n. mi. instead of the nominal 15.0 n. mi. Performance of the standard 130° transfer from TPI rendezvous lengthens the transfer time by approximately 15 minutes but lessens the ΔV required. An 80-fps radial maneuver was chosen so that the maximum range possible would be obtained without violation of the LM RCS impingement limit on the APS (55-sec burn duration). The 80-fps separation maneuver is 51.9 seconds in duration. Descent staging occurs 15 minutes prior to the 80-fps separation maneuver. The recommended sequence is as follows.

1. Perform 2-fps retrograde maneuver (CSM +X jets).

2. Stage.

3. Perform 2-fps posigrade maneuver (CSM -X jets).

Performance of this sequence will place the descent stage below and in front of the CSM as shown by the relative motion in figure 6.

Because the separation maneuver will place the ascent stage ahead and above the CSM, no recontact problems exist. The relative motion is shown in figure 4; the maneuver summary, in table V; MSFN tracking and daylight/darkness history, in figure 10.

7.0 CONCLUSION

The data and procedures presented in this document represent the operational lunar orbital alternate rendezvous plans for Apollo 10 (Mission F). The purpose of the document was to propose alternates that are feasible from a trajectory standpoint. The RTCC and RTACF procedures and processors will be used to compute the maneuvers in real time, and real-time maneuver targeting rather than preflight generated data will be relied upon for the alternate missions. The procedures and data do not vary significantly within the launch window with the exception of the g.e.t. of the maneuvers and the MSFN coverage. The plans were generated based on a launch date of May 17, 1969, and a lift-off time of $16^h 33^m 49.371^s$ G.m.t.; however, the plans are basically applicable to any launch date and time. These plans were designed to satisfy certain test objectives. A summary of test objectives related to the nominal rendezvous are presented in table VI, along with the author's estimated accomplishment of each test objective during each alternate rendezvous.

TABLE I.- MANEUVER SUMMARY FOR OPERATIONAL APOLLO 10 (MISSION F) RENDEZVOUS

Maneuver	Time, day:hr:min:sec, g.e.t.	Time since previous maneuver, min:sec	ΔV, fps	Ullage maneuver Δt[a], sec	Main engine Δt, sec	Thrust direction[b], deg	Propulsion system	Resultant orbit[c], h_a/h_p, n. mi.
Minifootball (CSM)	4:02:55:40.0	--	2.5	--	7.2	270.0	-X RCS (four-jet)	61.2/57.8
DOI	4:03:54:12.0	58:32.0	72.8	8.0	15.0 (10%) 11.5 (40%)	180.0	DPS	58.2/8.2
Phasing	4:05:06:35.0	72:23.0	193.5	8.0	26.0 (10%) 15.0 (F.T.P.)	26.0	DPS	194.4/9.8
Descent staging	4:06:53:29.0	106:54.0	--	--	--	--	--	--
Insertion	4:07:03:29.0	10:00.0	213.3	4.0	14.4	152.6	APS	43.6/9.8
CSI	4:07:54:40.0	51:11.0	50.5	--	32.1	0.0	+X RCS (four-jet)	45.9/43.1
CDH	4:08:52:41.0	58:01.0	5.8	--	3.7	270.0	-X RCS (four-jet)	46.2/42.8
TPI	4:09:29:16.0	36:35.0	24.9	--	15.8	27.1	+X RCS (four-jet)	62.3/43.0
TPF	4:10:11:41.0	42:25.0	31.5	--	39.8	305.3	-Z RCS (two-jet)	61.2/57.8

[a]Includes 0.5-second ullage overlap.

[b]Measured counterclockwise from direction of motion.

[c]Measured above landing site radius (0.8 n. mi. below mean radius).

TABLE II.- MANEUVER SUMMARY FOR ALTERNATE 1a, DPS UNSTAGED

Maneuver	Time, day:hr:min:sec, g.e.t.	Time since previous maneuver, min:sec	ΔV, fps	Ullage maneuver Δt^a, sec	Main engine Δt, sec	Thrust direction[b], deg	Propulsion system	Resultant orbit[c], h_a/h_p, n. mi.
Minifootball (CSM)	4:02:55:40.6	--	2.5	--	7.1	270.0	-X RCS (four-jet)	61.2/57.8
DOI	4:03:54:11.6	58:31.0	72.7	8.0	15.0 (10%) 12.5 (40%)	180.0	DPS	58.2/8.2
Phasing	4:05:06:34.4	72:22.8	193.5	8.0	26.0 (10%) 15.9 (F.T.P.)	26.0	DPS	194.7/9.6
Insertion	4:07:03:02.3	116:27.9	213.2	8.0	15.0 (10%) 42.9 (40%)	151.1	DPS	43.6/9.9
CSI	4:07:55:21.2	52:18.9	50.3	8.0	42.3 (10%)	0.0	DPS	43.8/43.6
CDH[d]	4:08:53:22.3	58:01.1	6.1	8.0	3.7 (10%)	270.0	DPS	46.2/42.8
TPI	4:09:29:15.6	35:53.3	24.8	8.0	16.8 (10%)	27.1	DPS	62.3/42.9
TPF (CSM)	4:10:11:26.6	42:11.0	31.6	--	90.0	126.3	+X RCS (four-jet)	62.3/42.9
Circular-ization (CSM)	4:12:23:03.1	131:36.5	26.1	20.0	2.2	0.0	SPS	62.3/62.2

[a] Includes 0.5-second ullage overlap.

[b] Measured counterclockwise from direction of motion.

[c] Altitude measured above landing site radius (0.8 n. mi. below mean radius).

[d] If $\Delta V < 4.0$ sec, the burn will be done with -X four-jet RCS.

TABLE III.- MANEUVER SUMMARY FOR ALTERNATE 1b, APS INOPERATIVE

Maneuver	Time, day:hr:min:sec, g.e.t.	Time since previous maneuver, min:sec	ΔV, fps	Ullage maneuver Δt[a], sec	Main engine Δt, sec	Thrust direction[b], deg	Propulsion system	Resultant orbit[c], h_a/h_p, n. mi.
Minifootball (CSM)	4:02:55:40.6	--	2.5	--	7.1	270.0	-X RCS (four-jet)	61.2/57.8
DOI	4:03:54:11.6	58:31.0	72.7	8.0	15.0 (10%) 12.5 (40%)	180.0	DPS	58.2/8.2
Phasing	4:05:06:34.4	72:22.8	193.5	8.0	26.0 (10%) 15.9 (F.T.P.)	26.0	DPS	194.7/9.6
Insertion	4:07:03:02.3	116:27.9	213.2	8.0	15.0 (10%) 42.9 (40%)	151.1	DPS	43.6/9.9
CSI	4:07:55:21.2	52:18.9	50.3	8.0	21.8 (10%)	0.0	DPS	45.8/43.6
CDH[d]	4:08:53:22.3	58:01.1	6.1	8.0	3.7 (10%)	270.0	DPS	46.2/42.8
Descent staging[e]	4:09:08:22.3	15:00.0	--	--	--	--	--	--
TPI	4:09:29:18.0	20:55.7	24.8	--	16.1	27.1	+X RCS (four-jet)	62.3/43.0
TPF	4:10:11:43.4	42:25.4	31.6	--	41.0	305.3	-Z RCS (two-jet)	61.2/57.8

[a]Includes 0.5-second ullage overlap.

[b]Measured counterclockwise from direction of motion.

[c]Altitude measured above landing site radius (0.8 n. mi. below mean radius).

[d]If $\Delta V < 4.0$ fps, the burn will be done with +X four-jet RCS.

[e]See section 6.2 for staging procedures.

TABLE IV.- MANEUVER SUMMARY FOR ALTERNATE RENDEZVOUS 2, APS ONLY

Maneuver	Time, day:hr:min:sec, g.e.t.	Time since previous maneuver, min:sec	ΔV, fps	Ullage maneuver Δt[a], sec	Main engine, Δt, sec	Thrust direction[b], deg	Propulsion system	Resultant orbit[c], h_a/h_p, n. mi.
Minifootball (CSM)	4:02:55:40.6	--	2.5	--	7.1	270.0	-X RCS (four-jet)	61.2/57.8
Descent staging[d]	4:03:39:28.7	43:48.1	--	--	--	--	--	--
DOI	4:03:54:28.7	15:00.0	28.2	4.0	1.9	180.0	APS	58.2/40.0
Phasing	4:04:53:56.0	59:27.3	57.7	4.0	4.0	0.0	APS	102.2/40.0
CSI	4:05:54:24.2	60:28.2	7.7	--	5.0	0.0	+X RCS (four-jet)	102.2/45.7
CDH	4:06:55:01.9	60:37.8	78.3	4.0	5.5	4.4	APS	46.1/42.8
TPI	4:07:30:10.9	35:09.0	24.9	--	15.9	27.2	+X RCS (four-jet)	62.2/42.9
TPF	4:08:12.36.4	42:25.5	31.8	--	40.5	305.3	-Z RCS (two-jet)	61.2/57.8

[a]Includes 0.5 second ullage overlap.

[b]Measured counterclockwise from direction of motion.

[c]Altitudes measured above landing site radius (0.8 n. mi. below mean radius).

[d]See section 6.3 for staging procedures.

TABLE V.- MANEUVER SUMMARY FOR ALTERNATE RENDEZVOUS 3, MODIFIED FOOTBALL

Maneuver	Time, day:hr:min:sec, g.e.t.	Time since previous maneuver, min:sec	ΔV, fps	Ullage maneuver Δt, sec	Thrust direction[a], deg	Propulsion system	Resultant orbit[b], h_a/h_p, n. mi.
Descent staging[c]	4:03:44:03.7	--	--	--	--	--	--
Separation	4:03:59:03.7	15:00.0	80.0	51.9	88.7	+X RCS (four-jet)	75.6/43.9
TPI	4:05:31:18.3	92:14.6	18.5	11.9	175.2	+X RCS (four-jet)	61.8/43.9
TPF	4:06:13:44.3	42:26.0	30.8	39.6	305.1	-Z RCS (two-jet)	60.9/58.1

[a]Measured counterclockwise from direction of motion.

[b]Altitudes measured above landing site radius (0.8 n. mi. below mean radius).

[c]See section 6.4 for staging procedures.

TABLE VI.- TEST OBJECTIVE SUMMARY

Detailed test objective	Estimated percent accomplished			
	DPS		APS	Modified football
	1a	1b	2	3
1. LM-active rendezvous	70	95	55	20
2. PGNCS undocked performance	100	100	--	--
3. LM/CSM/MSFN VOICE/TM	100	100	100	100
4. Lunar orbit visibility	100	100	40	40
5. Rendezvous radar performance	100	100	25	15
6. Landing radar test	100	100	--	--
7. LM supercritical helium	100	100	--	--
8. AGS/CES attitude/translation control	75	100	100	100
9. LM/AGS rendezvous evaluation	100	100	95	20
10. PGNCS/AGS monitoring	100	100	85	30
11. VHF ranging	100	100	100	100
12. Ground support lunar distance	100	100	100	100
13. LM IMU performance	100	100	100	100
14. AGS performance	100	100	50	50

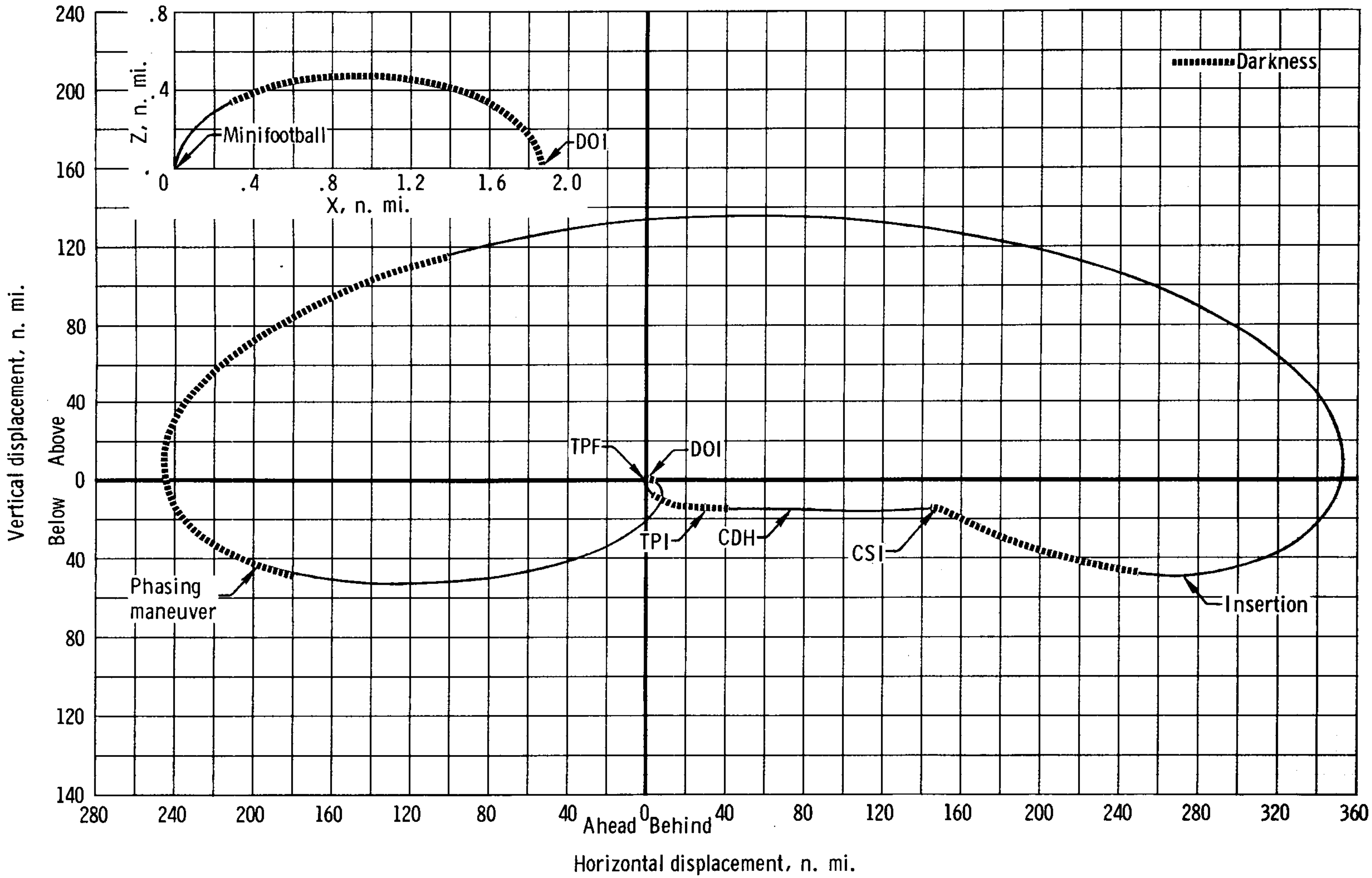


Figure 1. - Relative motion nominal rendezvous and alternates 1a and 1b.

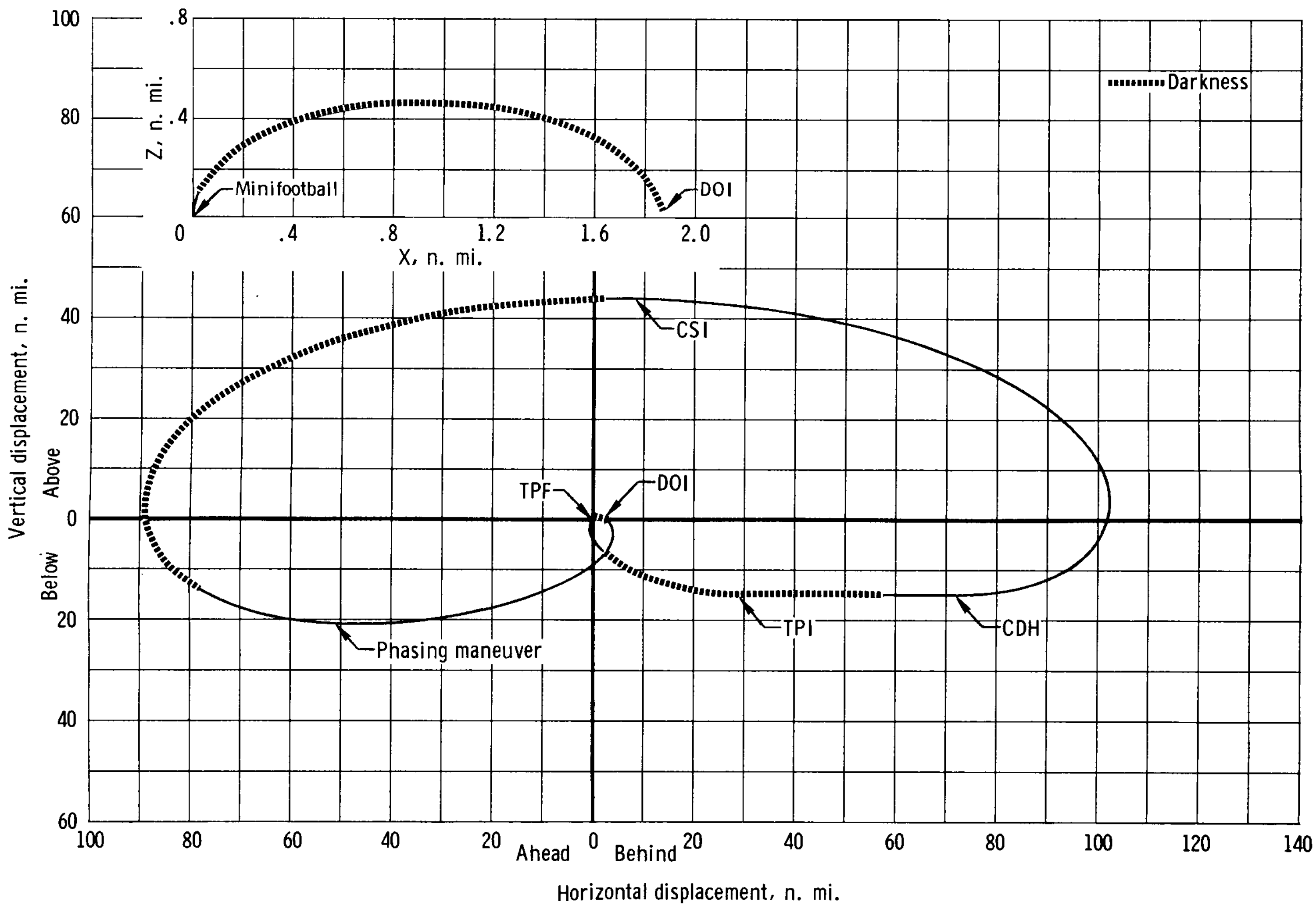


Figure 2. - Relative motion alternate 2, APS only.

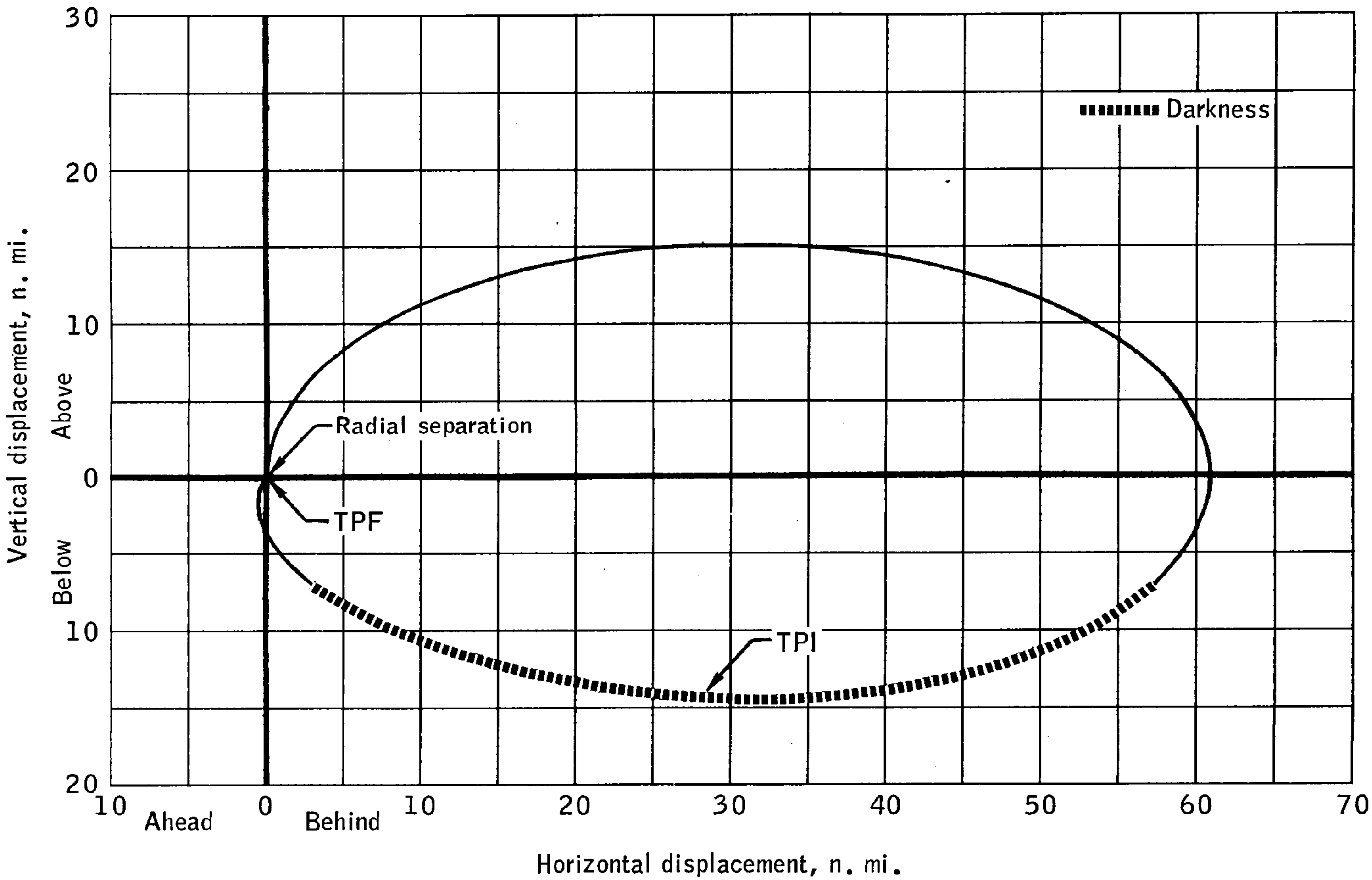


Figure 3.- Relative motion alternate 3, modified football.

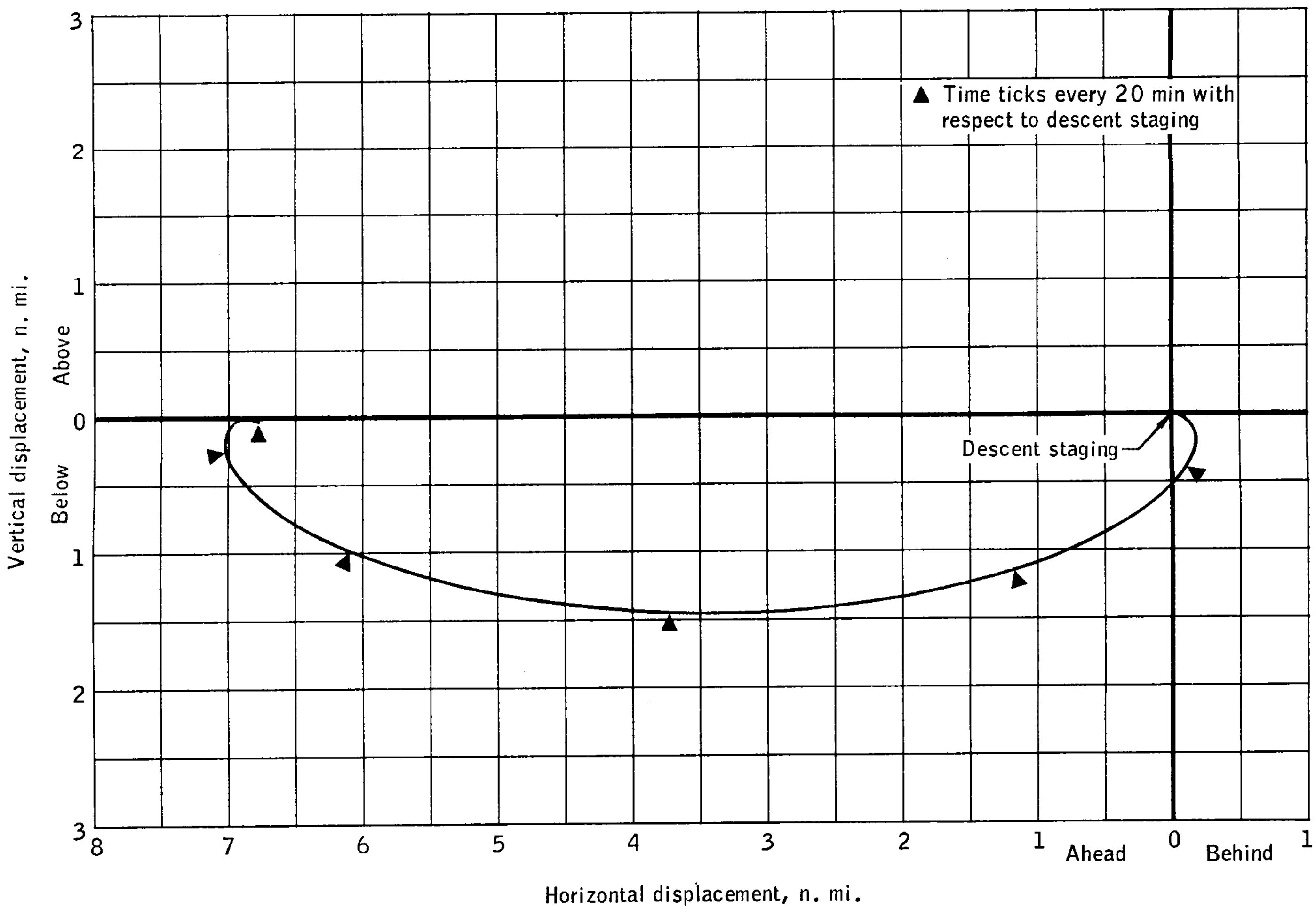


Figure 4.- Relative motion of descent stage with respect to the ascent stage for alternate 1b.

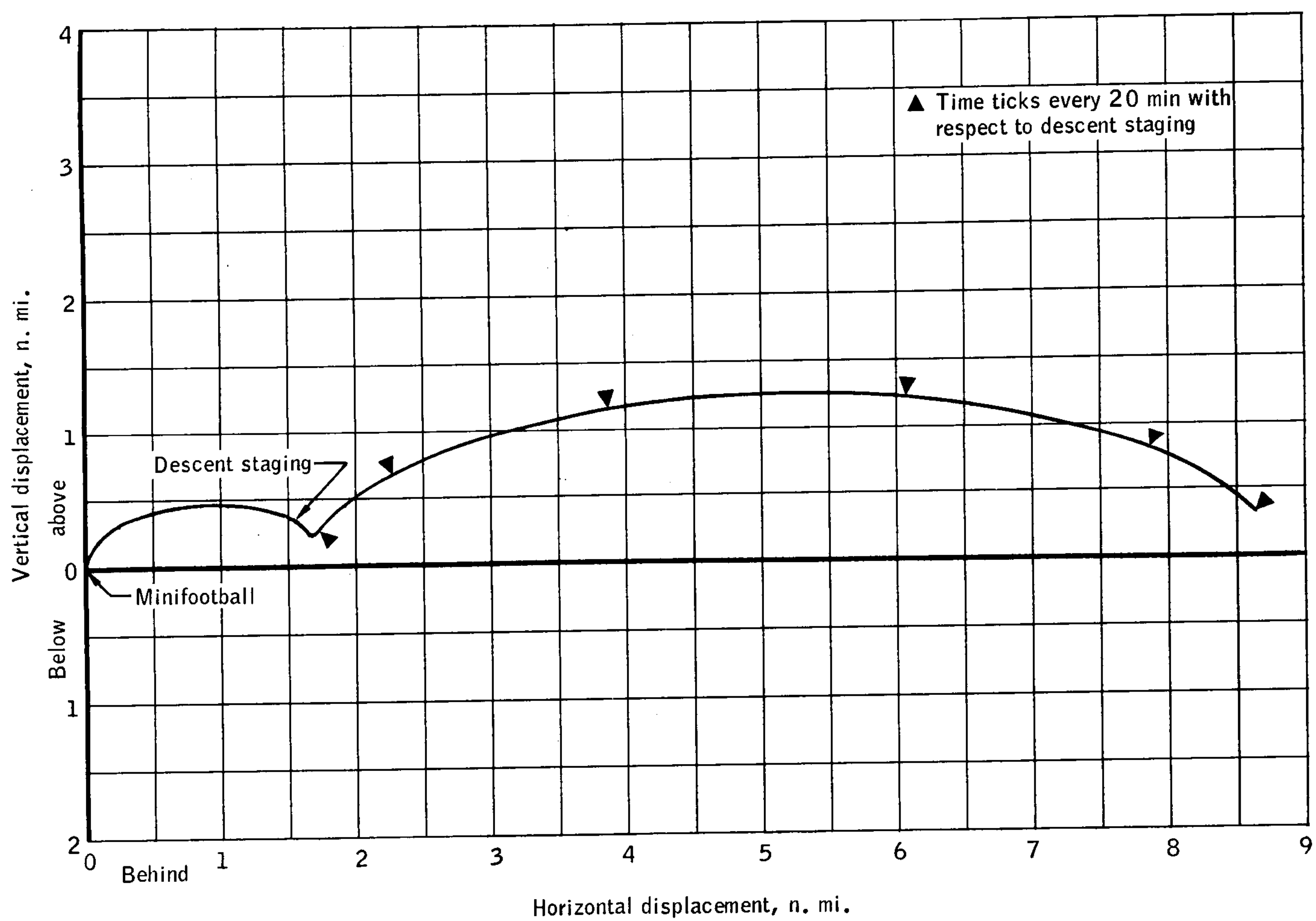


Figure 5.- Relative motion of descent stage with respect to CSM for alternate 2.

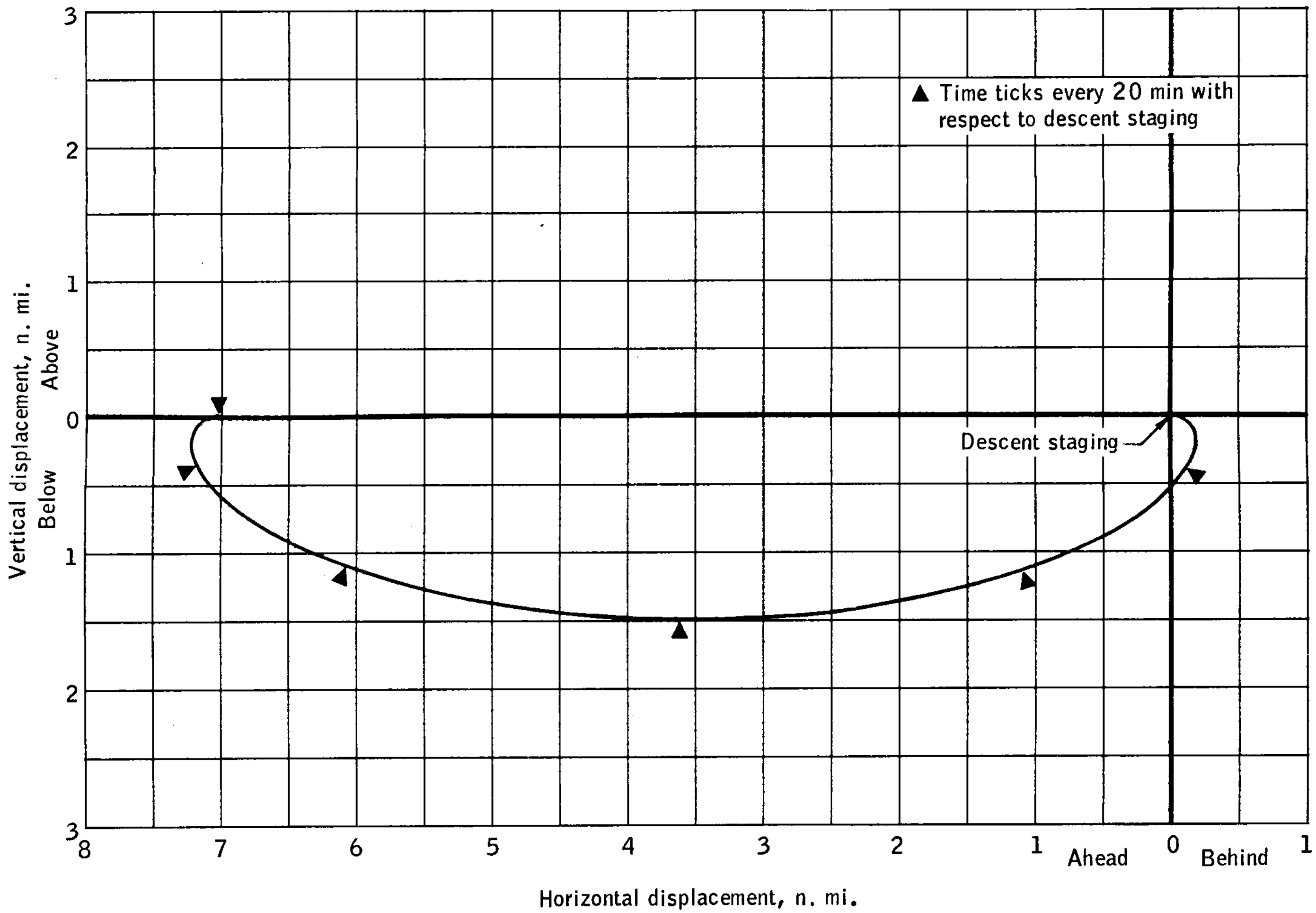
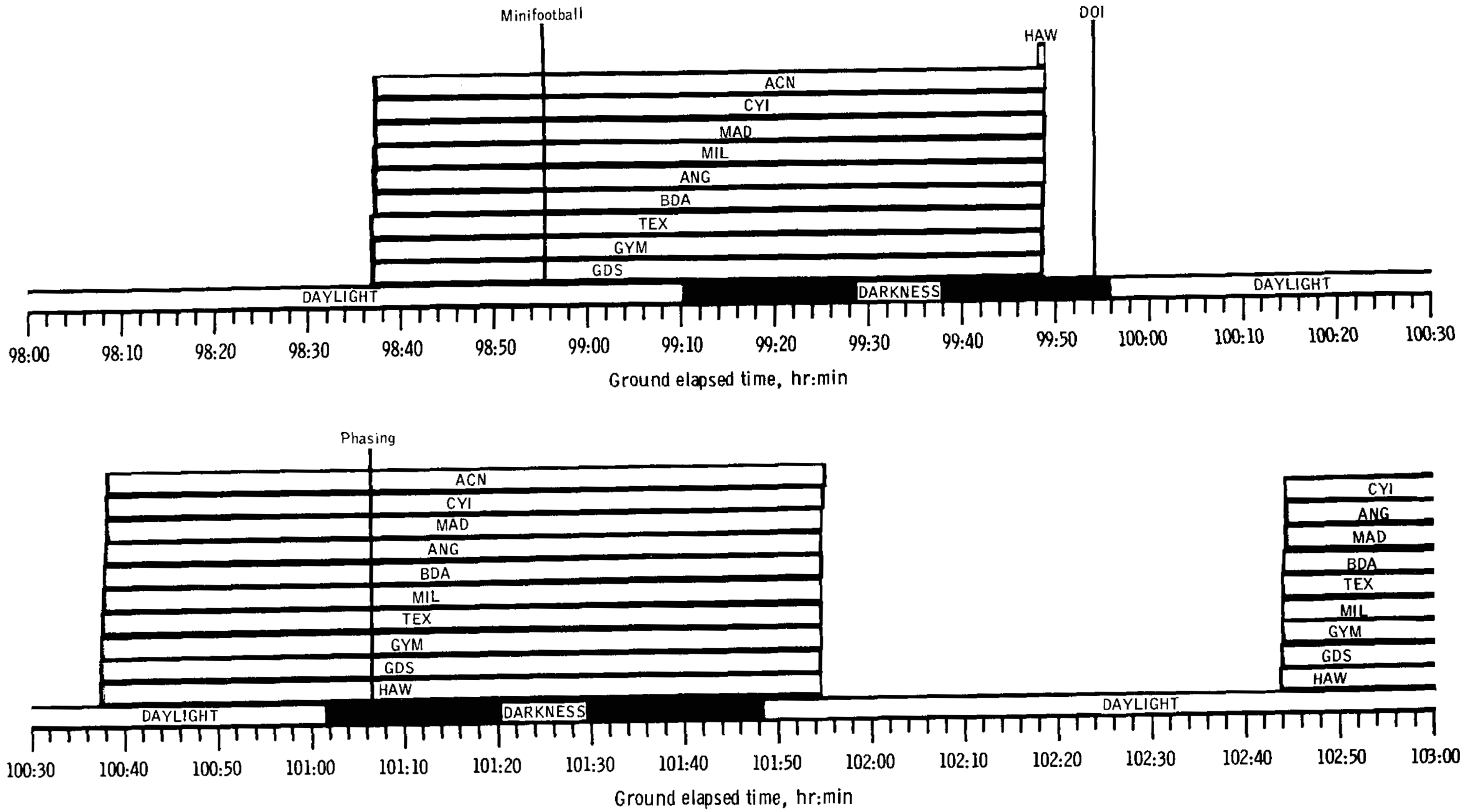
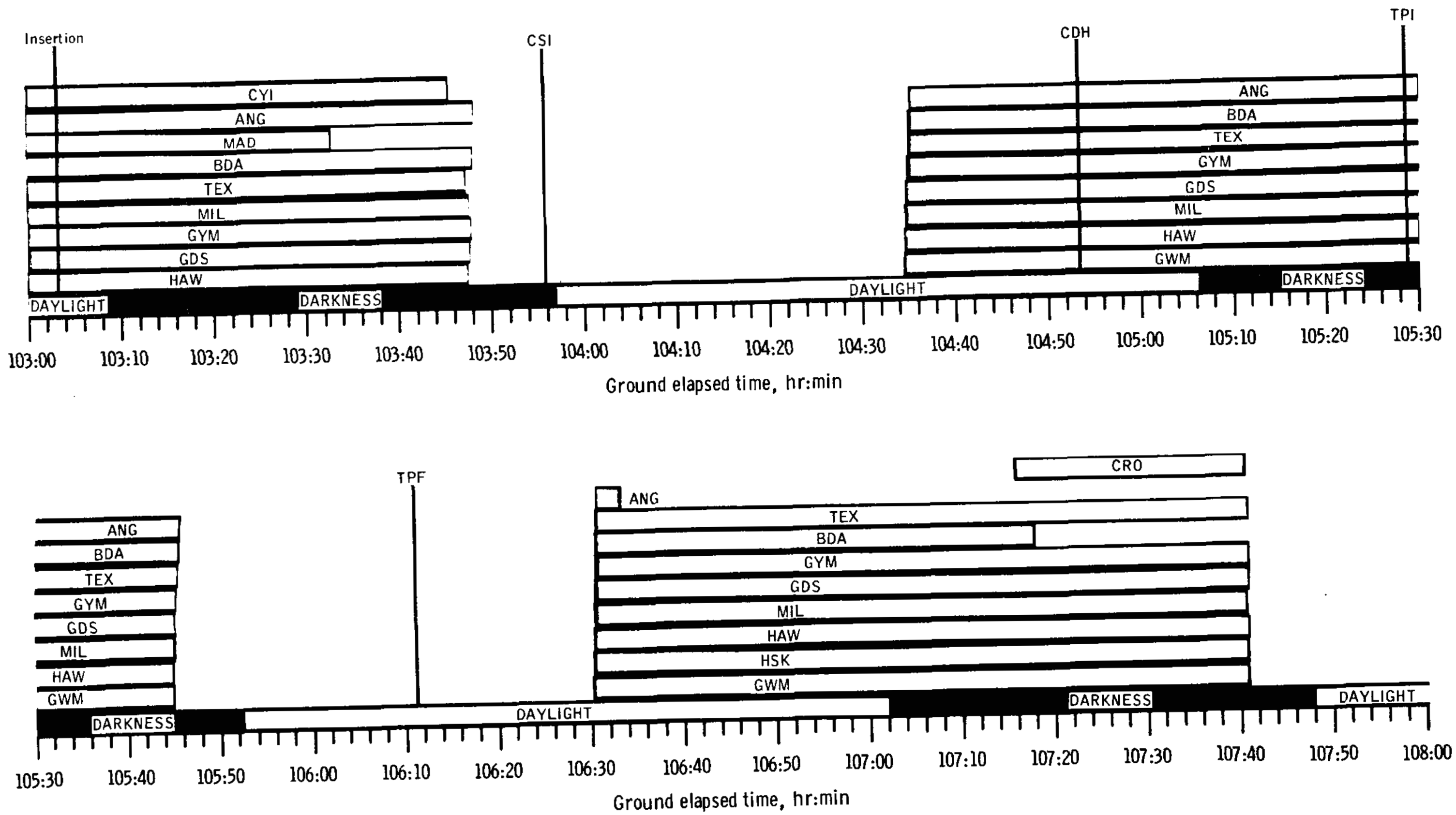


Figure 6.- Relative motion of descent stage with respect to the CSM for alternate 3.



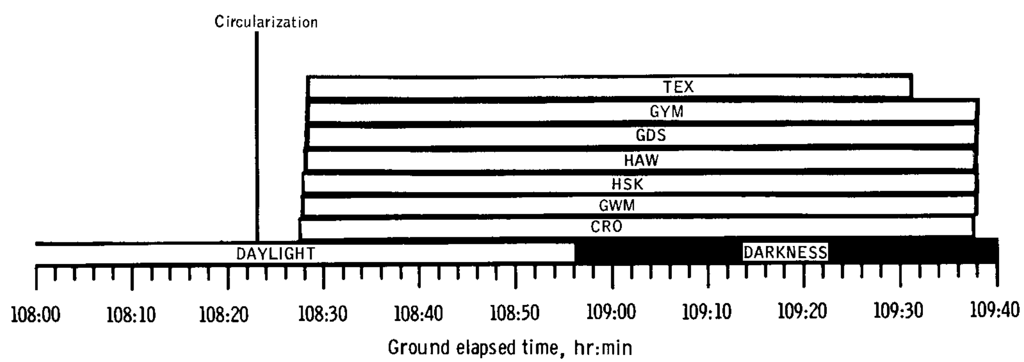
(a) 98:00 to 103:00.

Figure 7. - MSFN coverage and daylight/darkness summary for alternate 1a, DPS unstaged.



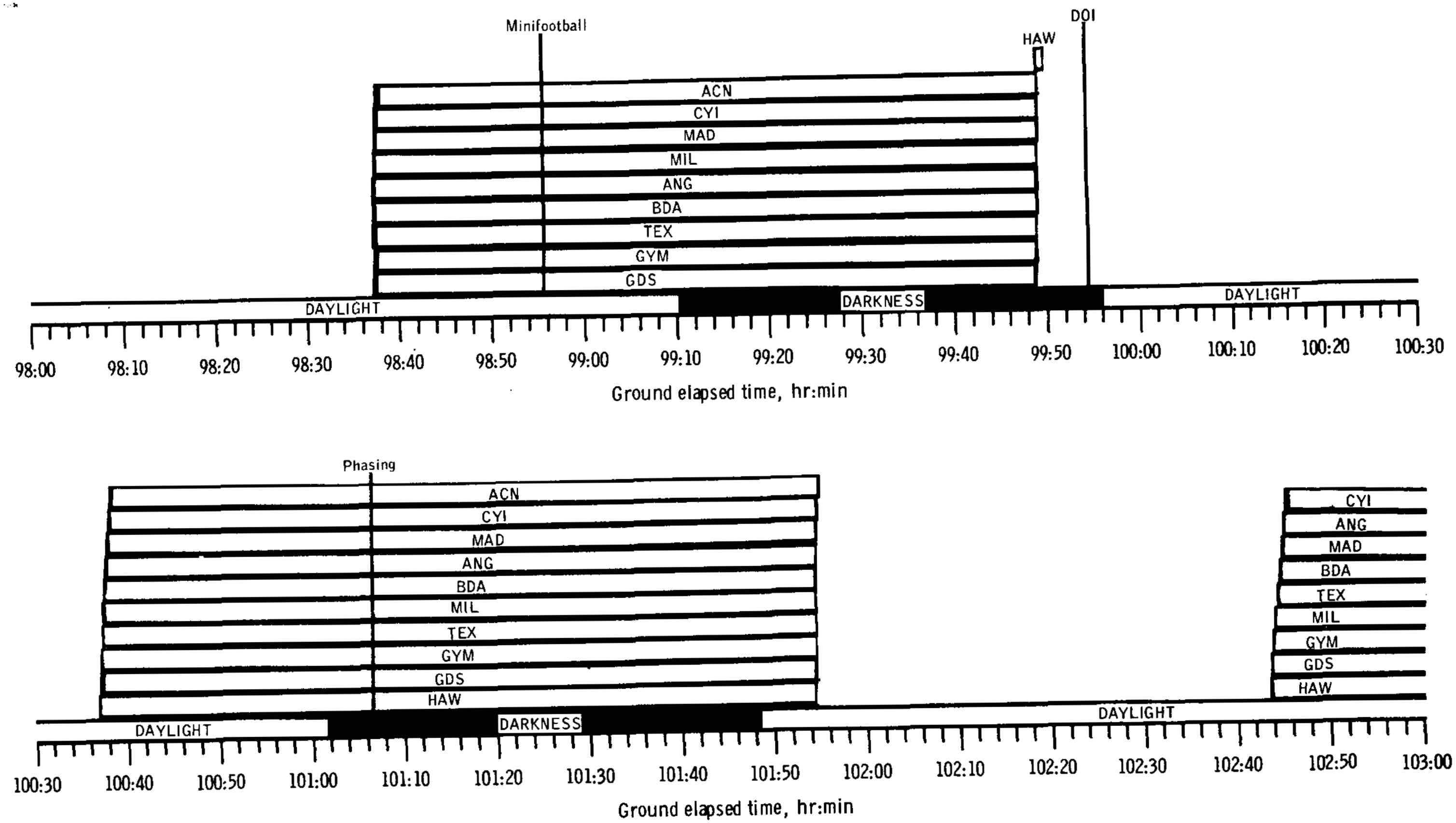
(b) 103:00 to 106:20.

Figure 7.- Continued.



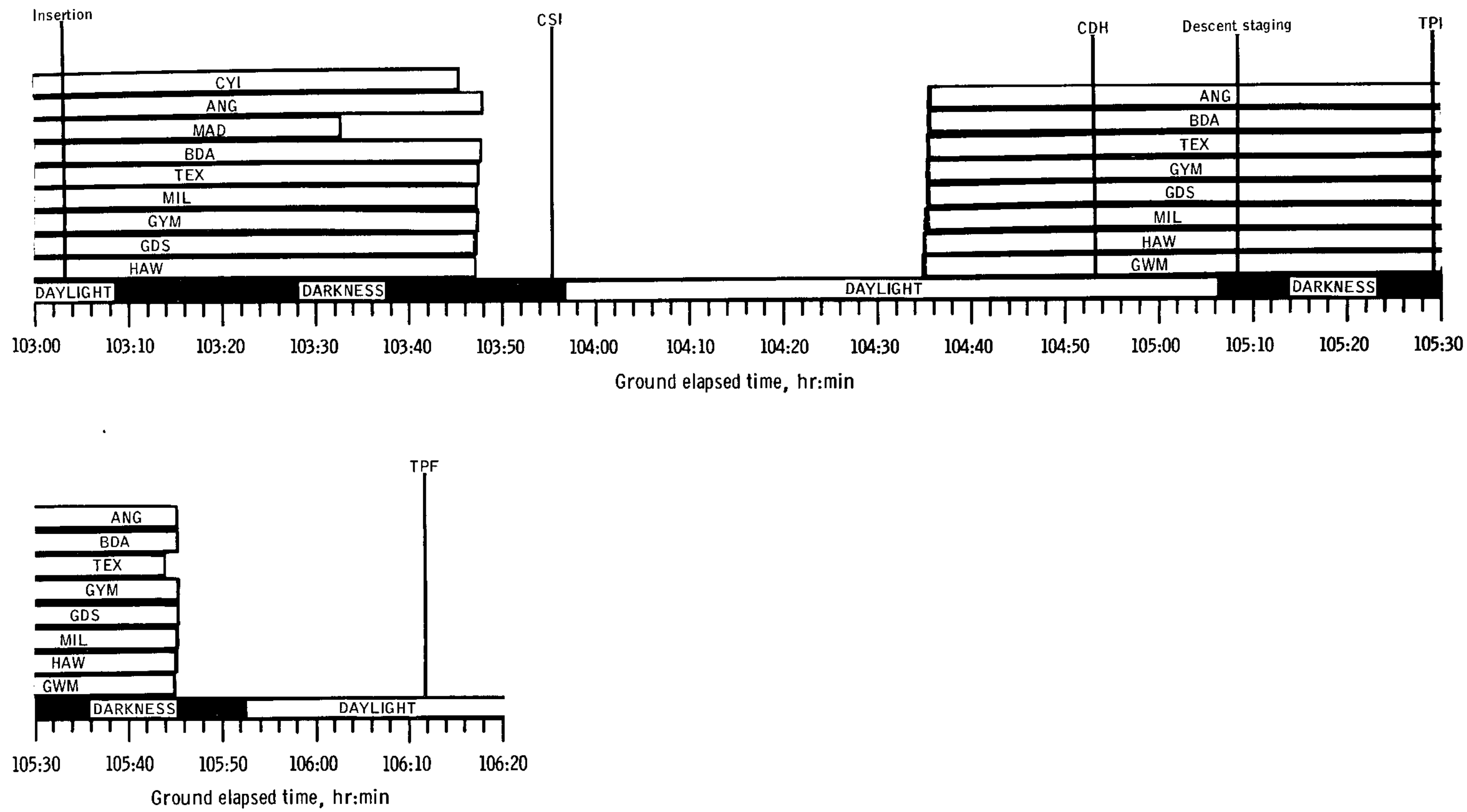
(c) 108:00 to 109:40.

Figure 7.- Concluded.



(a) 98:00 to 103:00.

Figure 8. - MSFN coverage and daylight/darkness summary for alternate 1b, APS inoperative.



(b) 103:00 to108:00.

Figure 8.- Concluded.

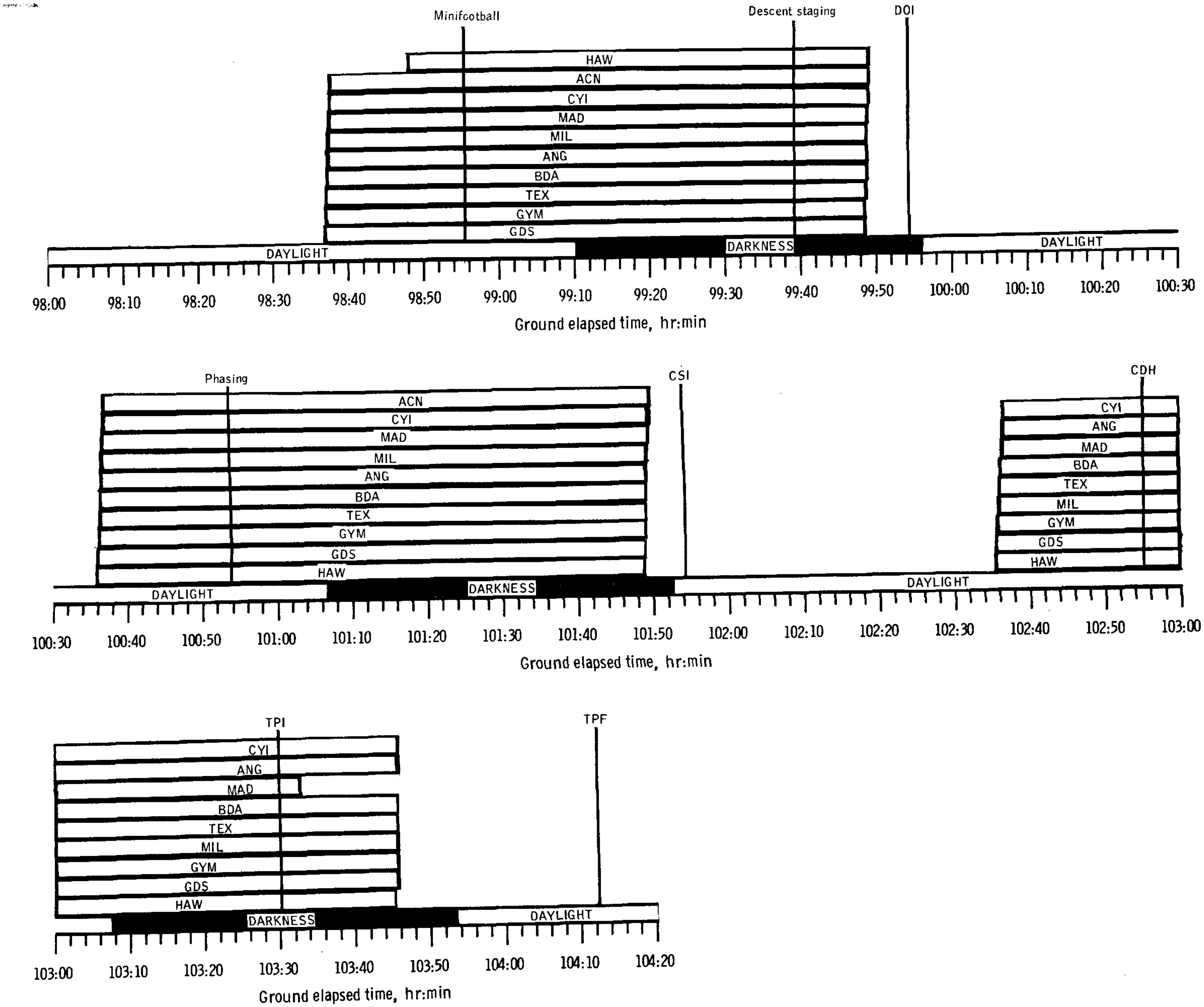


Figure 9. - MSFN coverage and daylight/darkness summary for alternate rendezvous 2, APS only.

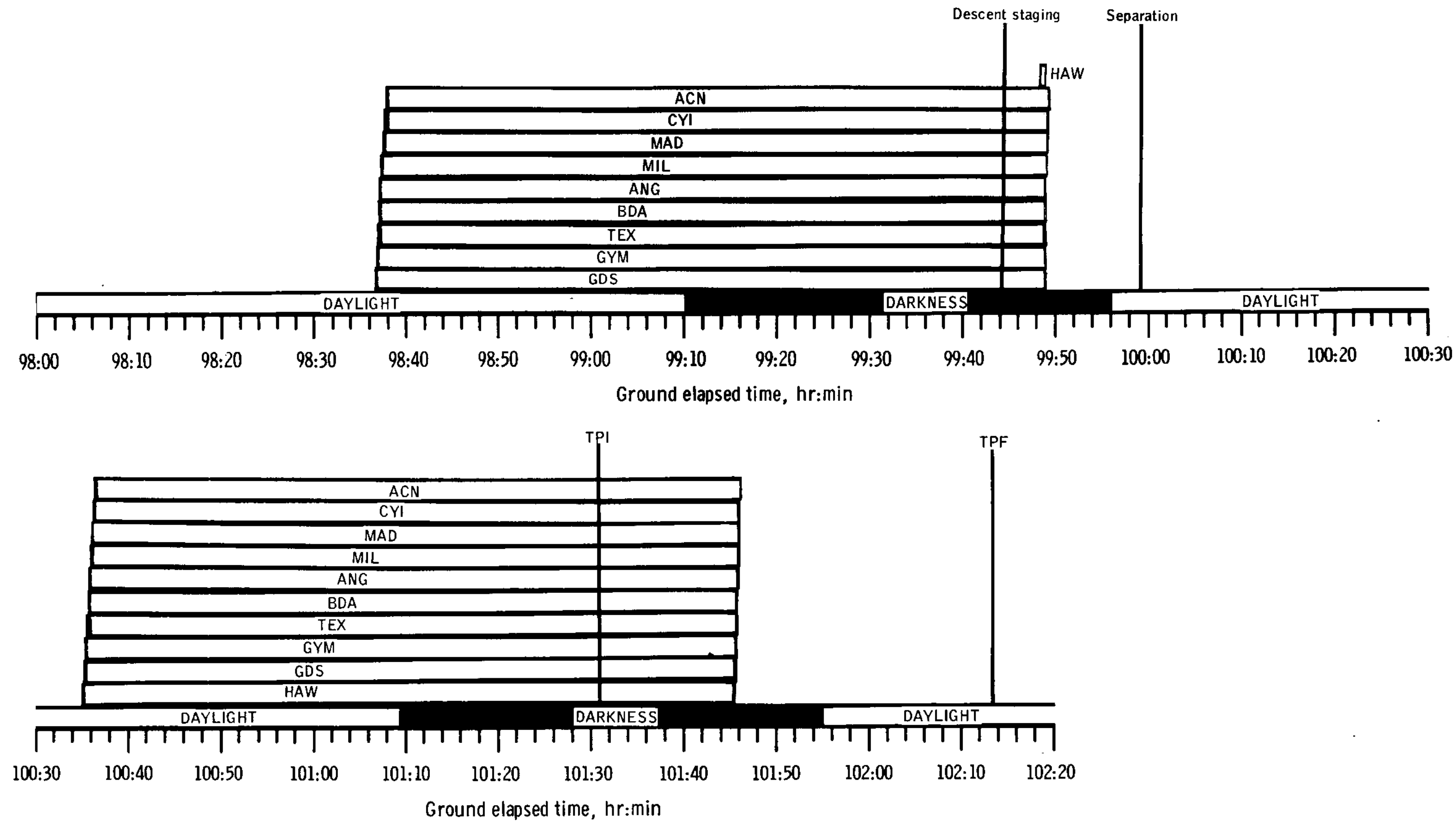


Figure 10. - MSFN coverage and daylight/darkness summary for alternate rendezvous 3, modified football.

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